Aerosol Radiative Effects Estimated from CERES

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Introduction

Estimating radiative effects of aerosol at the top of the atmosphere over the oceans is difficult because of the magnitude of the effect is small compared with variations in reflectivity of ocean surface. In addition, clear-sky scene identification is complicated such as identifying scattering by smokes and cloud particles and glint. Moreover, modeling the top of the irradiance for a molecular atmosphere is uncertain because of difficulty to model the reflection from the ocean surface. In this study, in order to eliminate uncertainty by theoretical models, we estimated the albedo of the atmosphere for a molecular atmosphere using VIRS-derived aerosol optical thickness and CERES-derived irradiance.

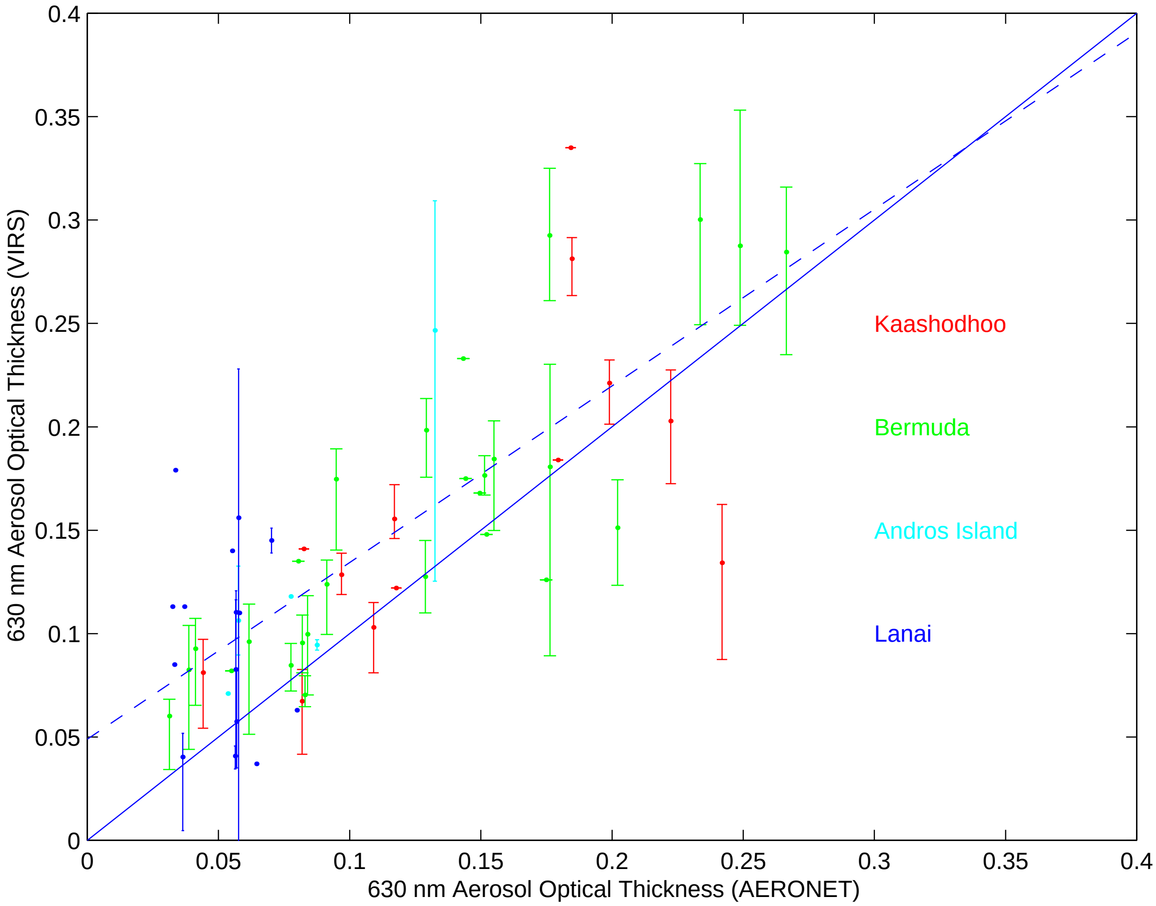


Figure 1: Comparison of aerosol optical thicknesses derived from VIRS by Stowe et al. (1997) and those provided by AERONET (1998). Four island sites are selected for the comparison. All sites are at the sea level. The slope of the regression line (dashed line) is 0.855 and the intercept is 0.049. Although non absorbing particles with the mode radius and standard deviation of 0.1 μm and 2.03, respectively, for their distribution are assumed in the retrieval algorithm, the agreement is good when VIRS-retrieved aerosol optical thicknesses are averaged.

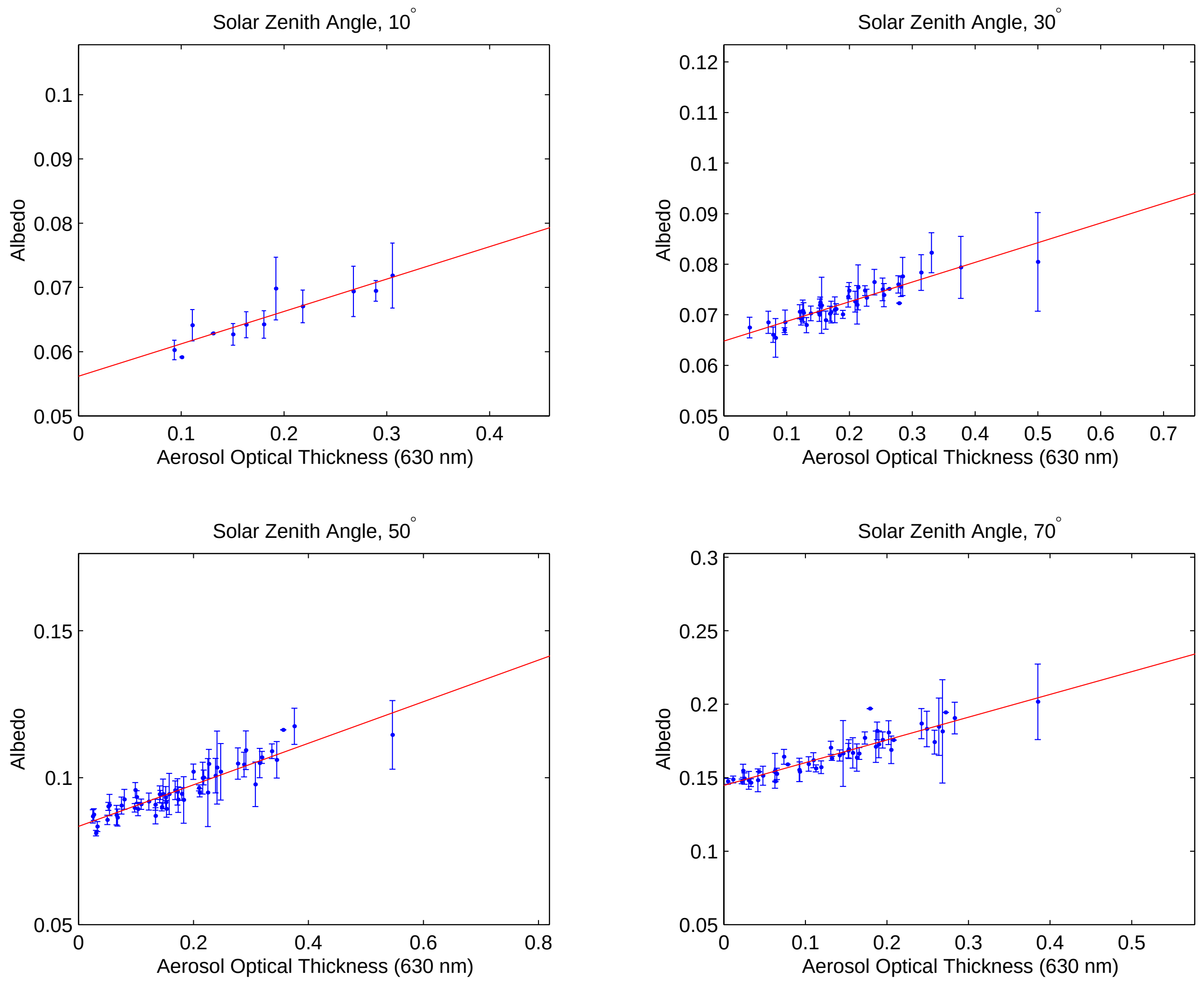


Figure 2: We stratify the albedo by the solar zenith angle using 1 degree bins. We then obtain the slope and intercept of the regression line for every one degree solar zenith angle by plotting the albedo versus aerosol optical thickness. The intercept of the regression line is the albedo of a molecular atmosphere for a given solar zenith angle.

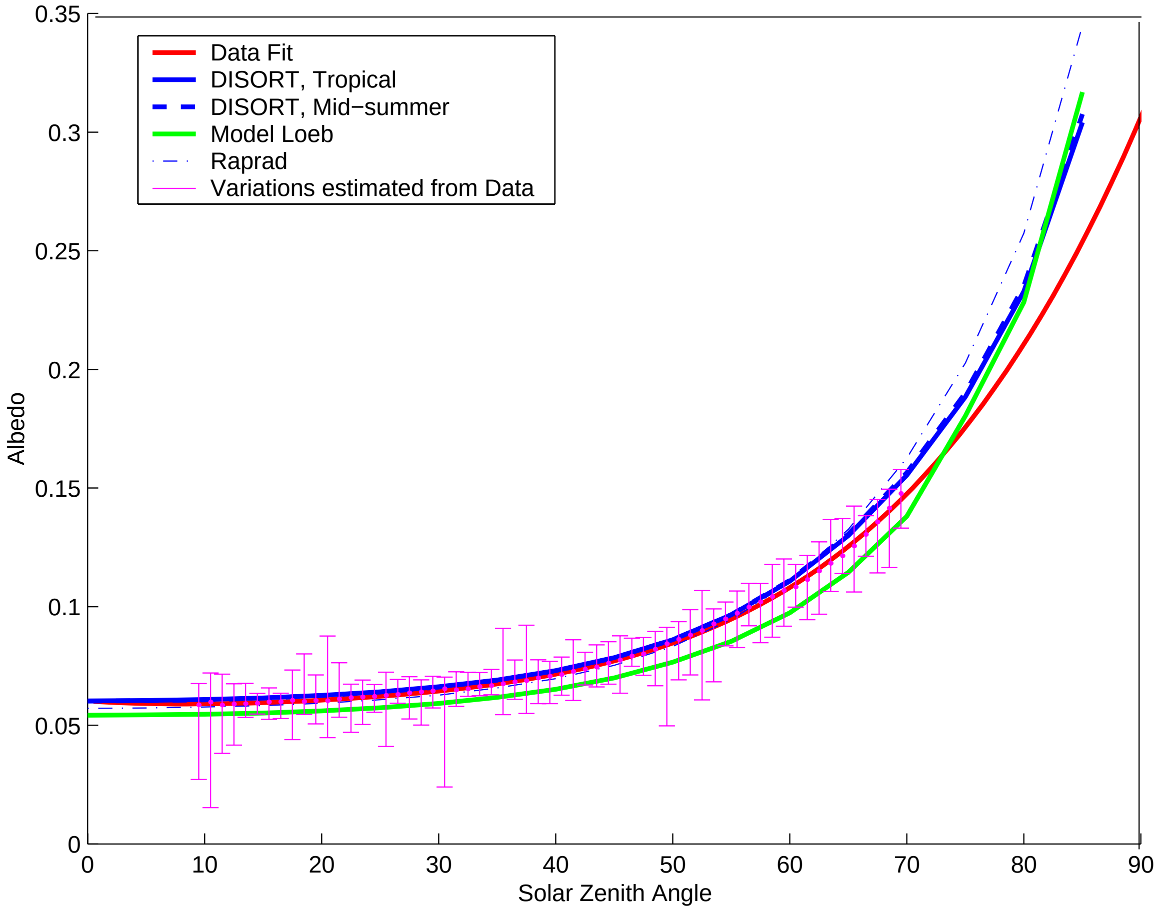


Figure 3: We use a 20 degree by 20 degree grid box between $\pm$ 40 degree latitude to perform above regressions. All intercepts are plotted as a function of solar zenith and are fitted by a fourth order of polynomial (led line). The vertical bars indicate the variation in the intercept (max. and min.) at every solar zenith angle. The solid blue line is the modeled albedo for a molecular atmosphere by DISORT including a ocean BRDF model. To model the albedo, we used standard tropical atmosphere and surface wind speed of 5ms^{-1}.

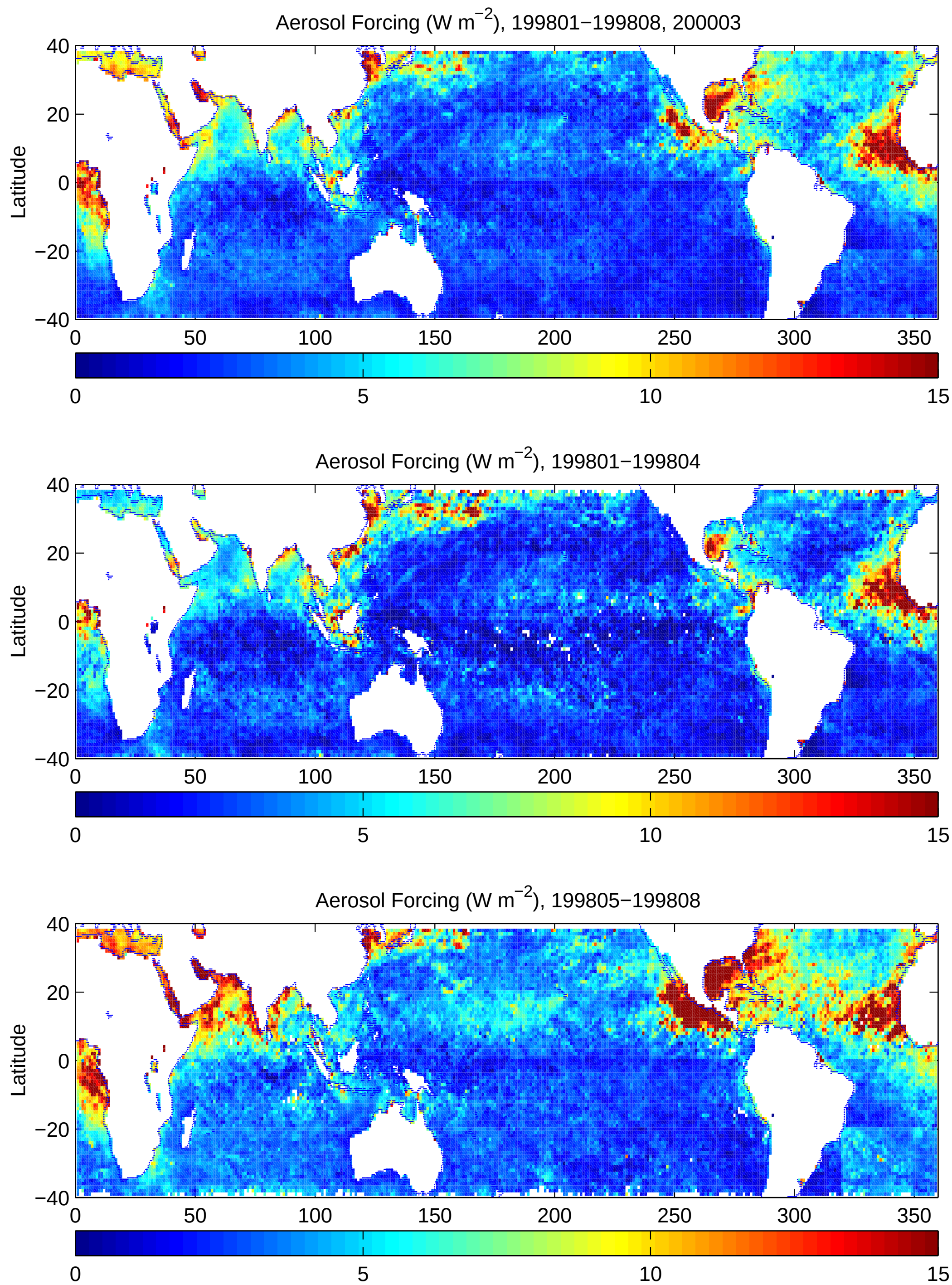


Figure 4: Estimated daily mean radiative forcing of aerosol at the top of the atmosphere averaged over 9 months (top), averaged over 4 month during northern hemisphere winter (middle), and during northern hemisphere summer (bottom). Forcing is defined as CERES-derived clear-sky irradiances minus irradiances for a molecular atmosphere, which is also estimated from CERES and VIRS data (see Figure 3). To compute the daily mean forcing, the forcing computed for a clear-sky footprint is multiplied by a fraction of daytime at the location and on the day of the measurement.

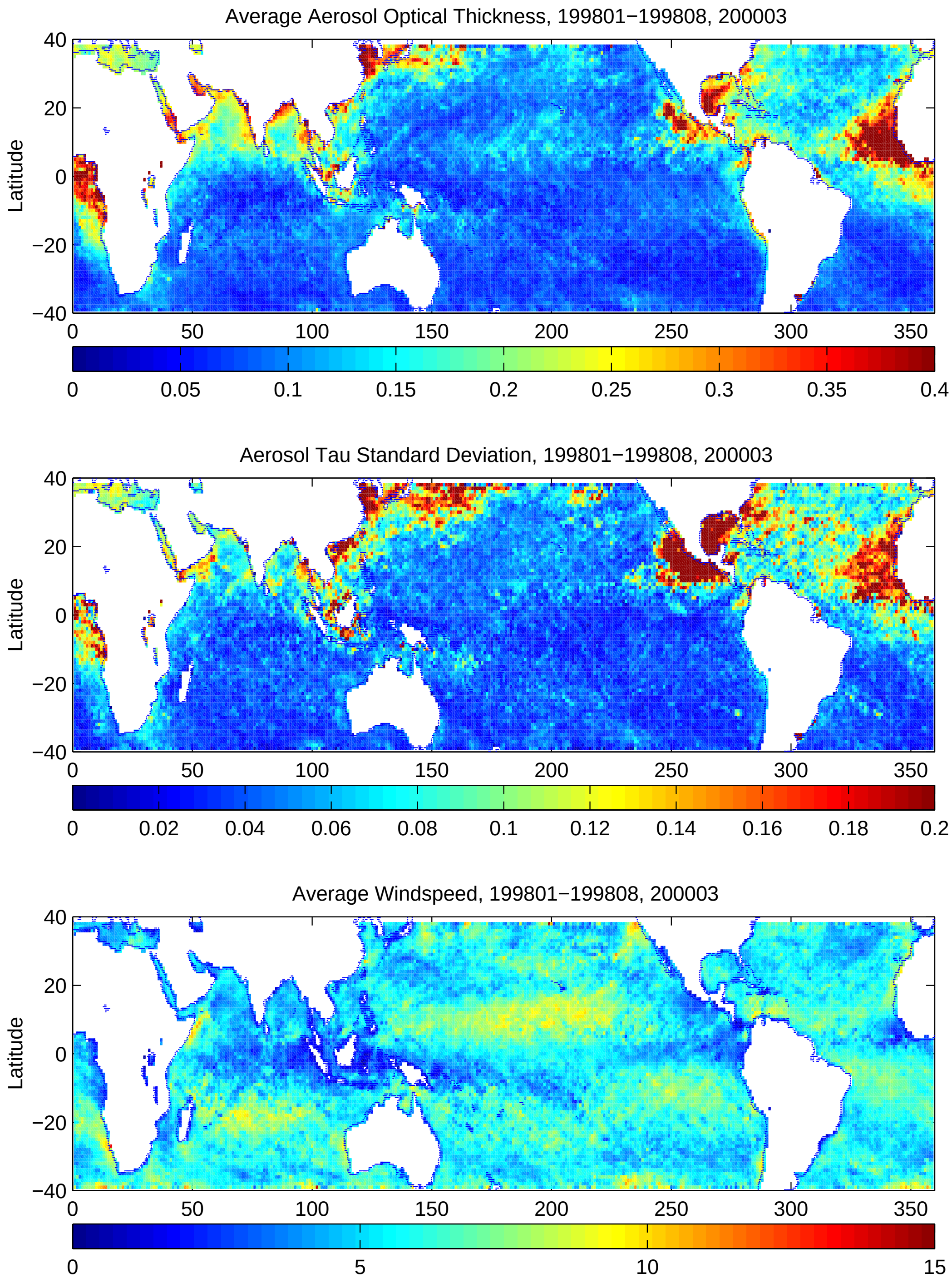


Figure 5: Top) Mean aerosol optical thickness estimated from VIRS by Stowe et al. (1997) over 9 months. Middle) Standard deviation of aerosol optical thickness. Locations of a large standard deviation might indicate locations of aerosol source. Bottom) Wind speed averaged over 9 months.

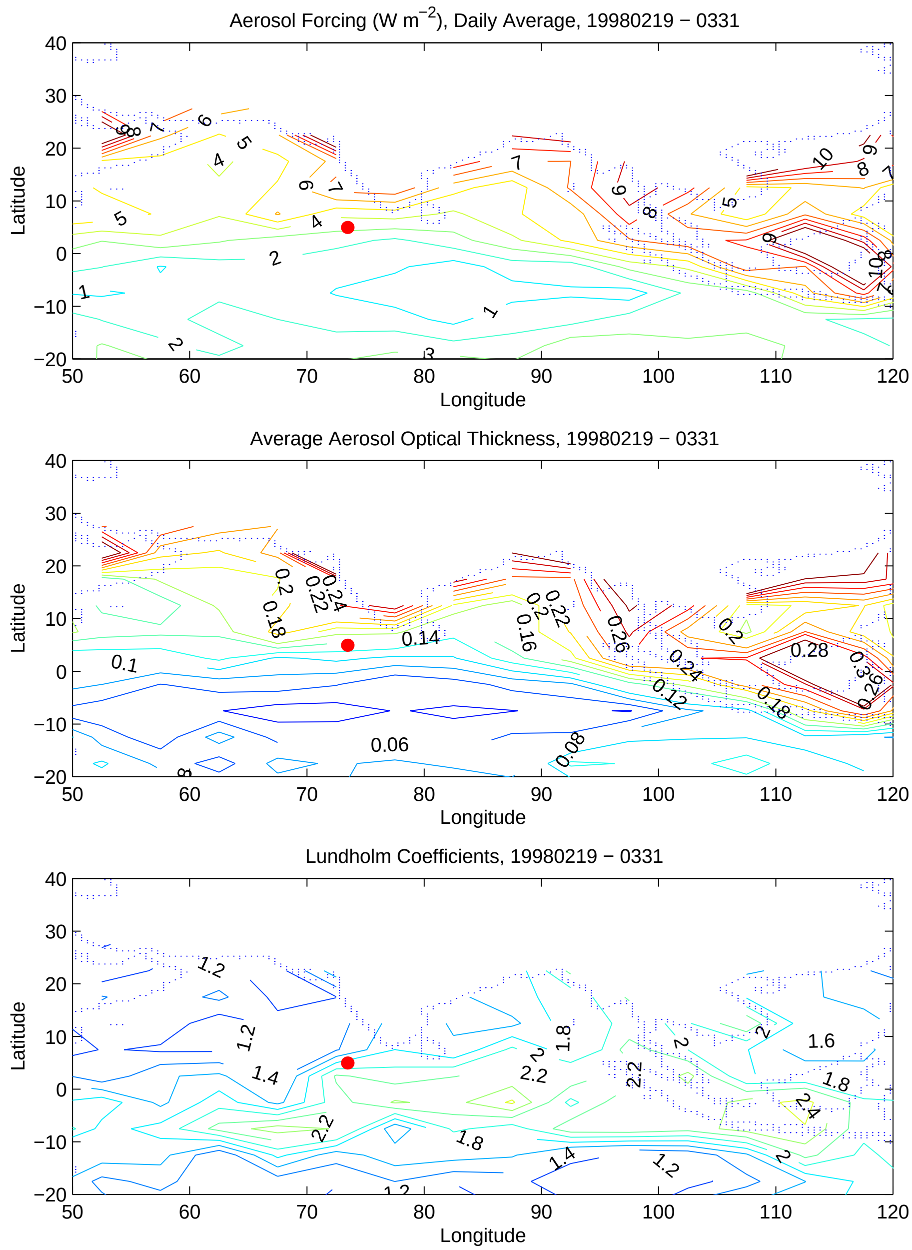


Figure 6: Radiative forcing, aerosol optical thickness, and Lundholm (Angstrom) coefficient estimated from CERES and VIRS averaged over the INDOEX period. The solid red circle indicate the location of the Kaashidhoo Climate Observatory. The mean aerosol optical thickness during this period observed from ground-based instrument is 0.125 at 670 nm and the mean Lundholm coefficient is 1.233 (Satheesh et al. 1999) Although the aerosol optical thickness at the Observatory agrees with the value given by Satheesh et al. (1999), the Lundholm coefficient does not agree with their value. The aerosol optical thickness decreases to the south, which agrees with measurements by Jayaraman et al (1998). The Lundholm coefficient increases to the south, which does not agree with their measurements. It might indicate problems in 1.6 μm optical thickness.

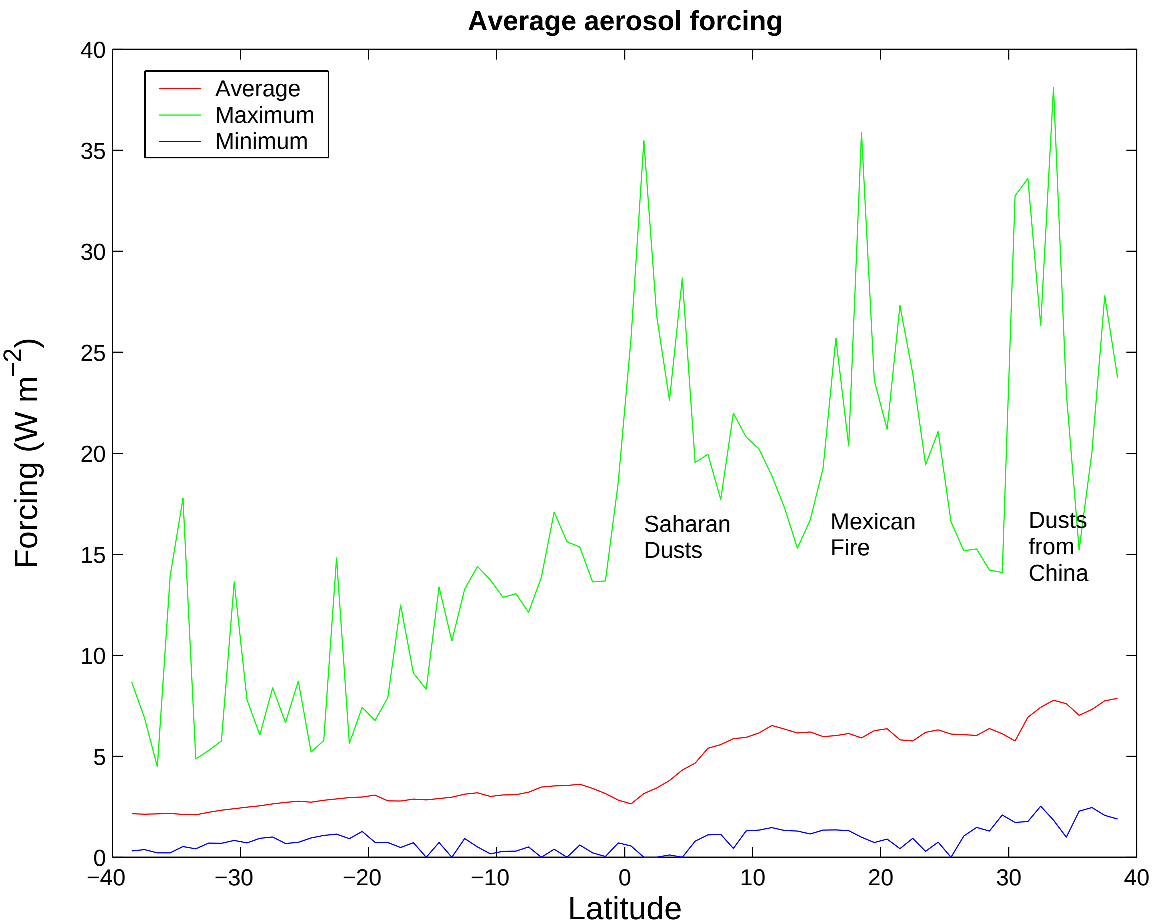


Figure 7: One degree zonally averaged aerosol forcing averaged over 9 months. It indicates that the northern hemisphere has a larger forcing then the southern hemisphere. The Magnitude of the forcing due to Saharan dusts, Mexican fire occurred in May 98, and dusts from China is approximately the same and can be as large as 30 Wm^{-2}.

Estimating Cloud Forcing Over the Oceans

The clear sky albedo A_c is given by

$$A_c = A_m + \frac{dA}{d\tau_a}\Delta\bar{\tau},$$

where A_m is the albedo of a molecular atmosphere, $\Delta\bar{\tau}$ is the albedo increase from molecular atmospheres due to aerosols averaged over 9 month. Since the aerosol optical thickness is derived by assuming a certain type of aerosol, derived aerosol optical thicknesses have errors. If we let the derived aerosol optical thickness $\tau\prime$, above equation can be written as

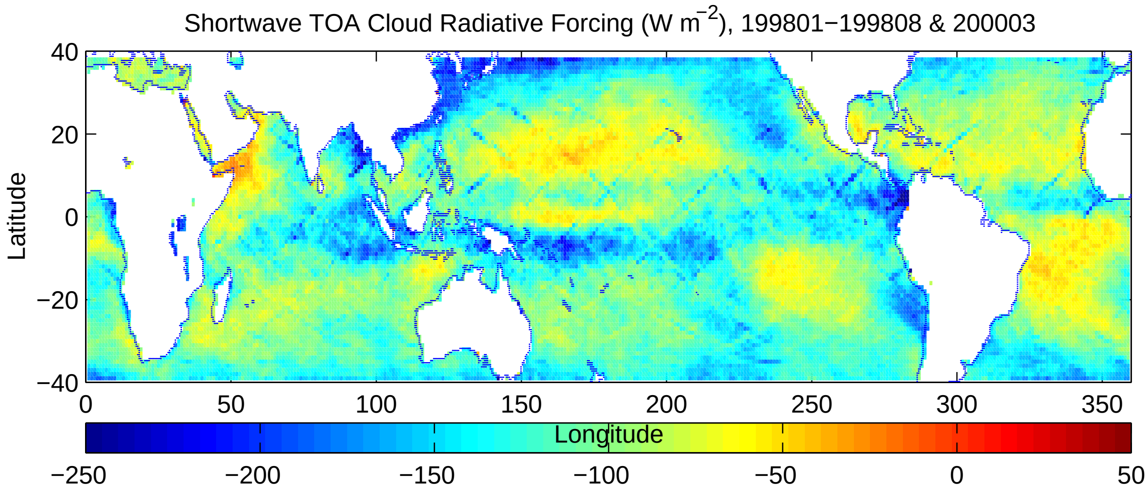
$$A_c = A_m + \frac{dA}{d\bar{\tau}'}\frac{d\bar{\tau}'}{d\bar{\tau}}\Delta\bar{\tau}.$$

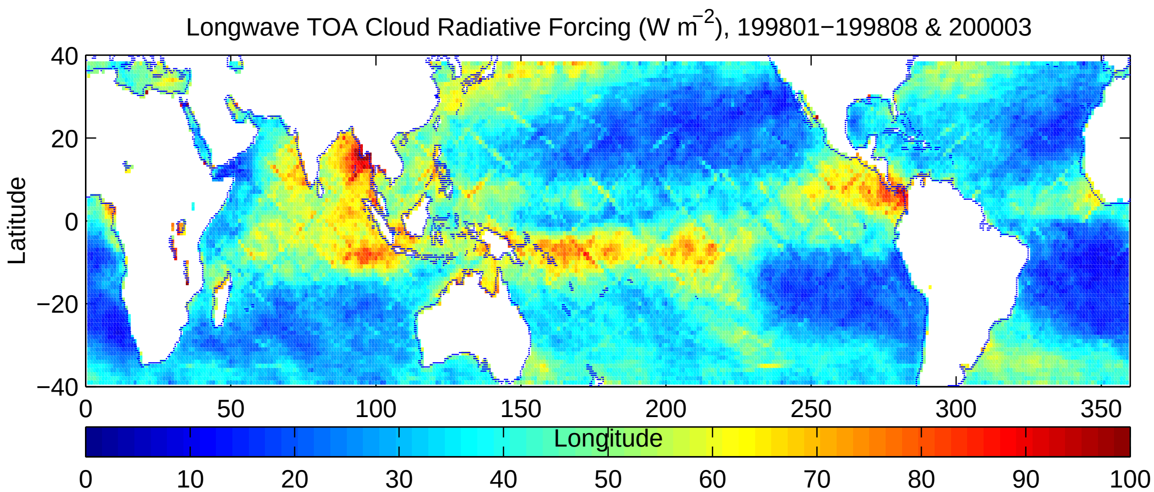
Since

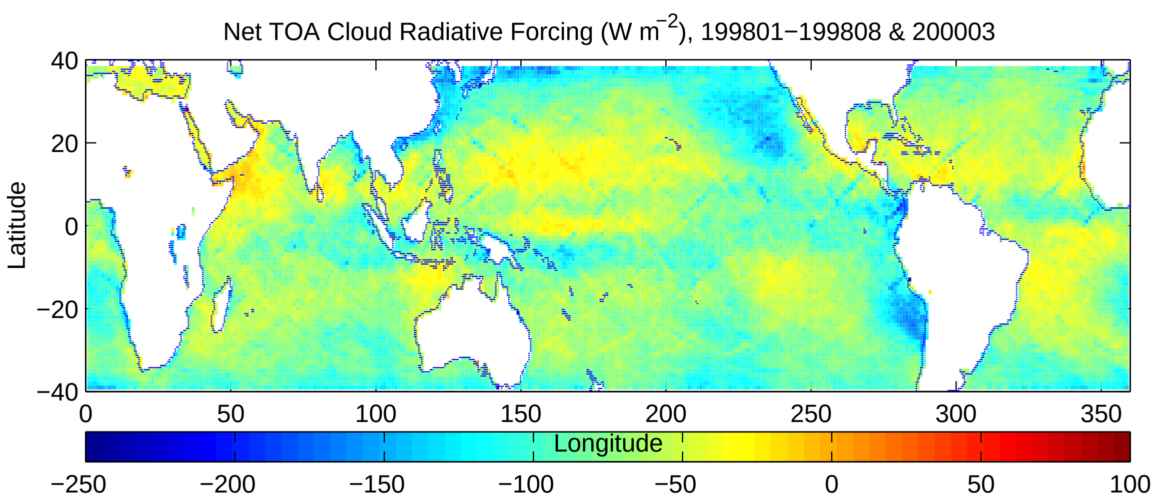
$$\frac{d\bar{\tau}'}{d\bar{\tau}}\Delta\bar{\tau} = \Delta\bar{\tau}'$$

$$A_c = A_m + \frac{dA}{d\bar{\tau}'}\Delta\bar{\tau}'.$$

Therefore, we expect that the error in the estimated albedo increase due to aerosol is smaller than the error in the aerosol optical thickness if the error in ADM is small. If we use the fitted relation to the intercept for A_m, and we also obtain a empirical relation for $dA/d\bar{\tau}'$ and multiply by $\bar{\tau}'$ for a given location, we can compute clear sky irradiance for the given location at any solar zenith angle. Figure 8 shows the shortwave cloud forcing estimated by this method (top) longwave cloud forcing and net radiative forcing (bottom).


Shortwave TOA Cloud Radiative Forcing (W m^{-2}), 199801−199808 & 200003
Latitude
40
20
0
−20
−40
0
50
100
150
200
250
300
350
Longitude
−250
−200
−150
−100
−50
0
50


Longwave TOA Cloud Radiative Forcing (W m^{-2}), 199801−199808 & 200003
Latitude
40
20
0
−20
−40
0
50
100
150
200
250
300
350
Longitude
0
10
20
30
40
50
60
70
80
90
100


Net TOA Cloud Radiative Forcing (W m^{-2}), 199801−199808 & 200003
Latitude
40
20
0
−20
−40
0
50
100
150
200
250
300
350
Longitude
−250
−200
−150
−100
−50
0
50
100

Conclusions

1. Regression intercepts provide a reasonable estimate of the albedo of a molecular atmosphere.
2. While VIRS derived aerosol optical thickness is consistent with surface measurements, Lundholm (Angstrom) coefficients might have problems due to problems in 1.6 μm optical thickness.
3. The zonally and daily averaged aerosol radiative effect at the top of the atmosphere is 6 to 7 Wm^{-2} in the northern hemisphere and 2 to 3 Wm^{-2} in the southern hemisphere.
4. The effect by fire or dusts could reach the daily average of more than 30 Wm^{-2}.

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